Observations of Frodingham 5 Sheet Piles at Bainbridge Island
10/04/16

The Frodingham 5 (F5) sheet piles have been in service for approx. 15 years. The 1870 ft wall of F5 sheet piles is experiencing excessive corrosion at a level I have not witnessed in 25 years of reviewing sheet pile structures globally. After only 15 years of exposure parts of the web (11.9 mm) have reduced to approx. 5 mm indicating a **rate of corrosion loss of 0.46 mm per year**. This is for the atmospheric zone which usually has minimal corrosion loss being above the splash zone (although there is indication that splash has actually topped the upper wall level) due to corrosion products on the rear upper area.

At the **rate of loss in the atmospheric zone** the wall **will lose structural integrity in less than five years** and will be penetrated leading to loss of fill, in approx. 10 years. The **Splash and Low water zone timeframe will be much less**.

These corrosion rates are around four times typical temperate climate corrosion rates for a Splash zone, not for Atmospheric, and are twice highest probability rates. However given the porous backfill conditions at the Wyckoff site and free movement of groundwater behind the piles from tidal action there is good cause to expect a similar degree of corrosion action on the rear of the wall as on the exposed side. This will effectively double average rates.

The Splash and Low Water zones were not measured but their rates of loss will be severe given the amount of corrosion products and severe lamination of the steel. It is highly recommended that thickness measurements are taken to establish exactly how much of this portion of the wall actually remains.

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The appearance of a black outer crust with a bright orange interior at various locations around the Low water zone indicates the presence of Sulphate reducing bacteria. Local sewage outfalls or leaks from septic tanks could be a source as well as discharge from local shipping. This will lead to excessive pitting corrosion in patches across the wall length. This accelerated low water corrosion occurs at or below Low water and is microbially induced. Rates are typically 0.5 mm/side/year on average to the point of complete perforation. Sulfates in the water are converted into hydrogen sulphide that cause anaerobic corrosion. Thickness measurements in the low water areas will define the degree of corrosion attack although some of the sites may be obscured by the marine fouling.

Several areas along the wall had clear seepage from the contained (contaminated) soils spreading out from the locks toward the sea bed although there is no indication of excessive corrosion at those locations.

Slide 3 shows the corrosion products at the Splash zone with general oxidation above that in the Atmospheric zone.

Slide 4 shows what appears to be a fabrication by the contractor possibly due to a damaged pile during driving.

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Slide 6 & 7 shows one of a number of piles that were completely or partially de-clutched. The completely de-clutched pile in pile 7 was likely never clutched at all. The partially de-clutched piles were most likely de-clutched during hard driving.

Slides 8 & 9 clearly show the excessive loss of thickness from the steel laminating even at the top of the piles in what should be a more protected zone. The remaining steel thickness here is a cause for concern. The corrosion around the lock itself is so severe that the lock no longer has any connection structurally and could easily de-clutch under load.

Slides 10,11 & 12 indicate excessive abrasion of the lock knuckle on the exterior in-pan on a number of piles. This has caused the finger to be completely worn away at the bed level. Based on visual inspection and reference to a CAD of the F5 around 21 mm of lock has been removed. This has occurred along a number of piles at the front (North?) face of the wall.
One cause may be abrasion from highly aggressive eddy currents at bed level churning up the sand bed. However it's unusual to have such abrasion without any visible scour.

The wall alignment overall is not good and indicates difficult driving conditions forcing the wall line out of positional placement in a number of locations. This would account for the isolated de-clutching noted above.

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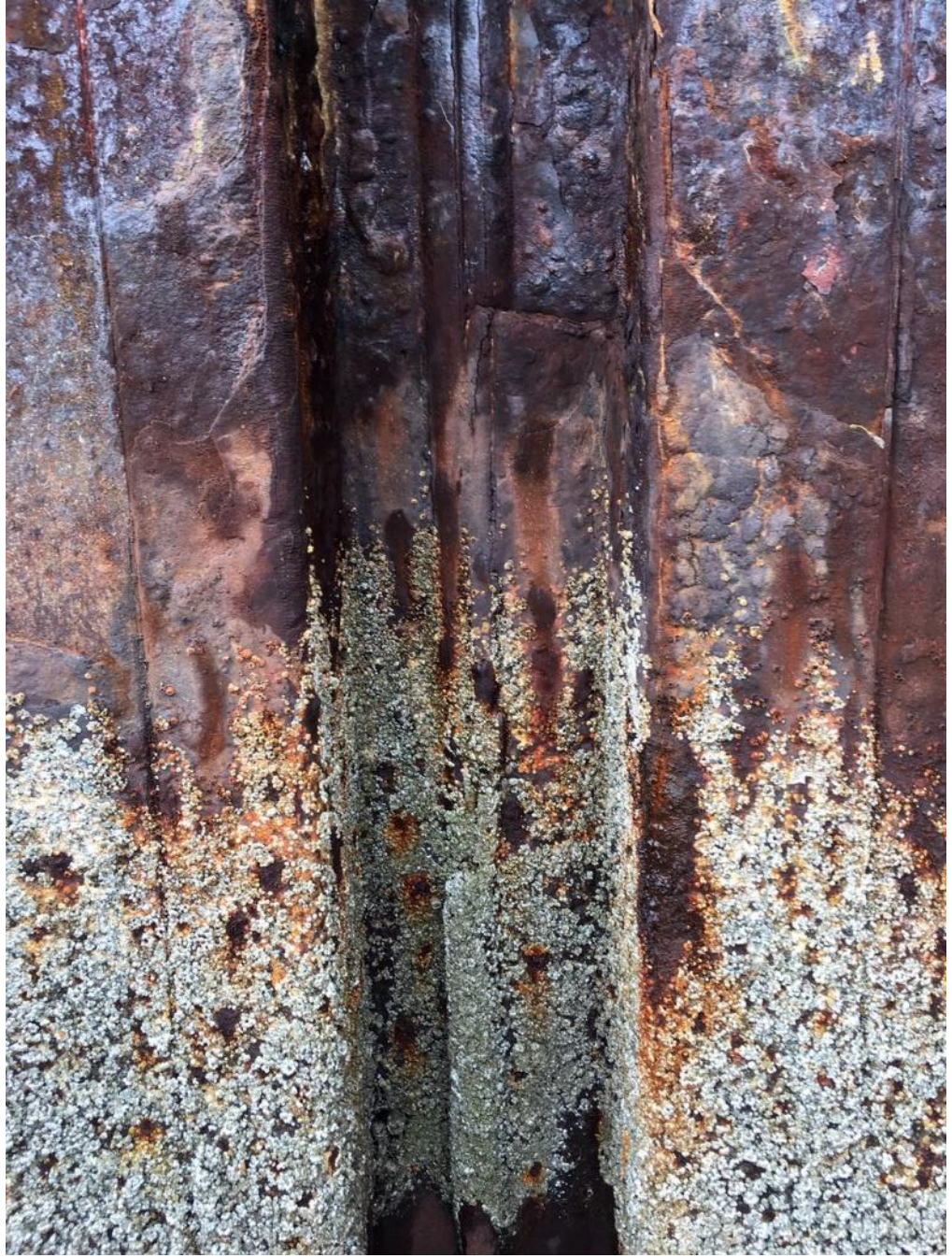
The overall severity of deterioration of the sheet piles in a relatively short period of time is most unusual. Other factors may be attributable here including impurities in the steel not being adequately removed during steel making. This would lead to embrittlement of the steel and micro cracking on the surface during rolling.

The vertical cracking along the lock is not a normal form of breakdown of steel on a sheet pile. It suggests a higher level of stress across the lock surface and may have been propagated from micro cracks in the steel.

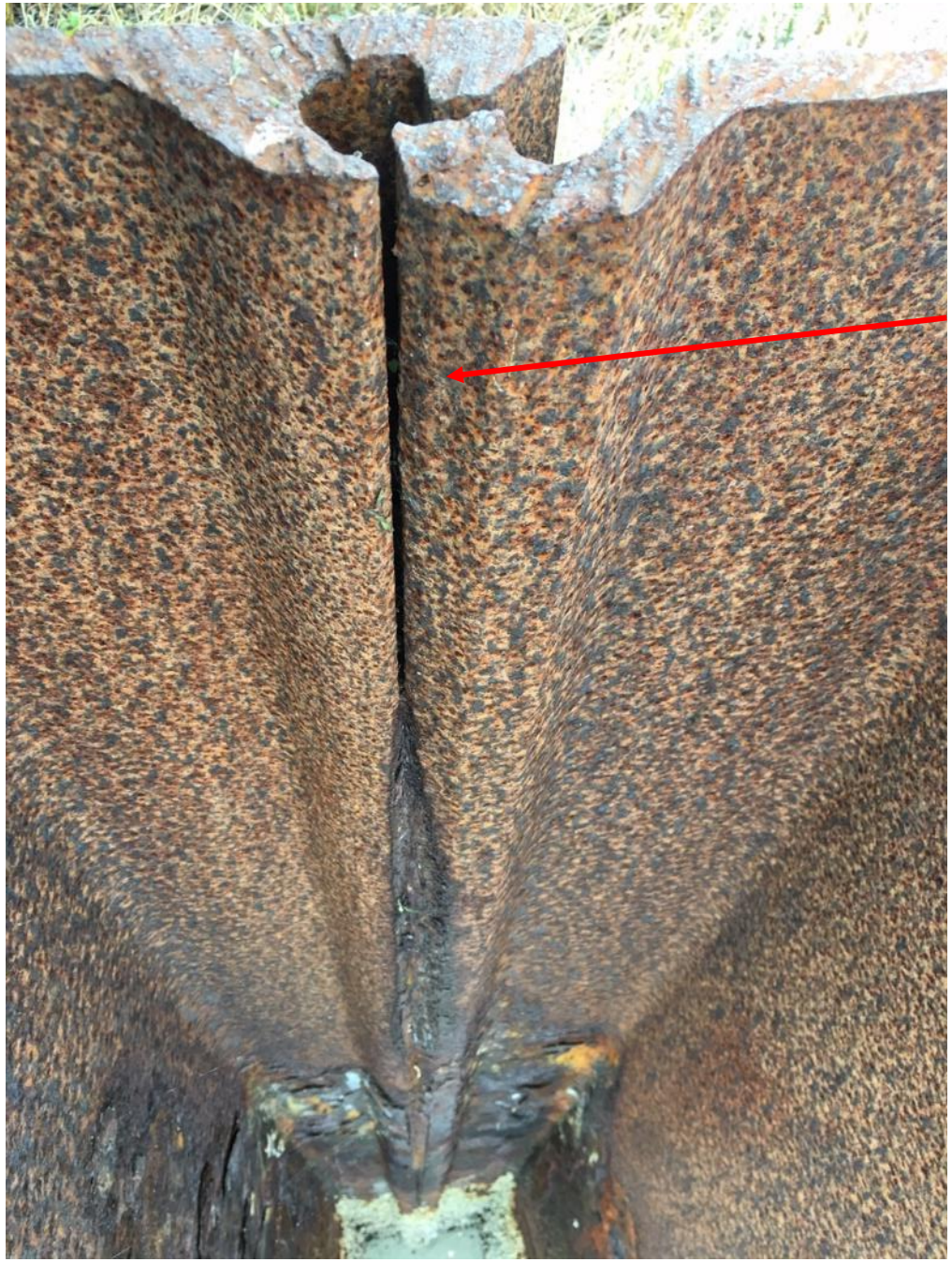
This wall does not have much service life remaining. Further thickness measurements will help determine how much remains. There should be sufficient time to allow for any remedial action program to be initiated.

Typical corrosion pattern throughout.
Atmospheric corrosion
followed by aggressive
Splash zone corrosion products.



Appears to be a contractor splice

Pile de-clutching



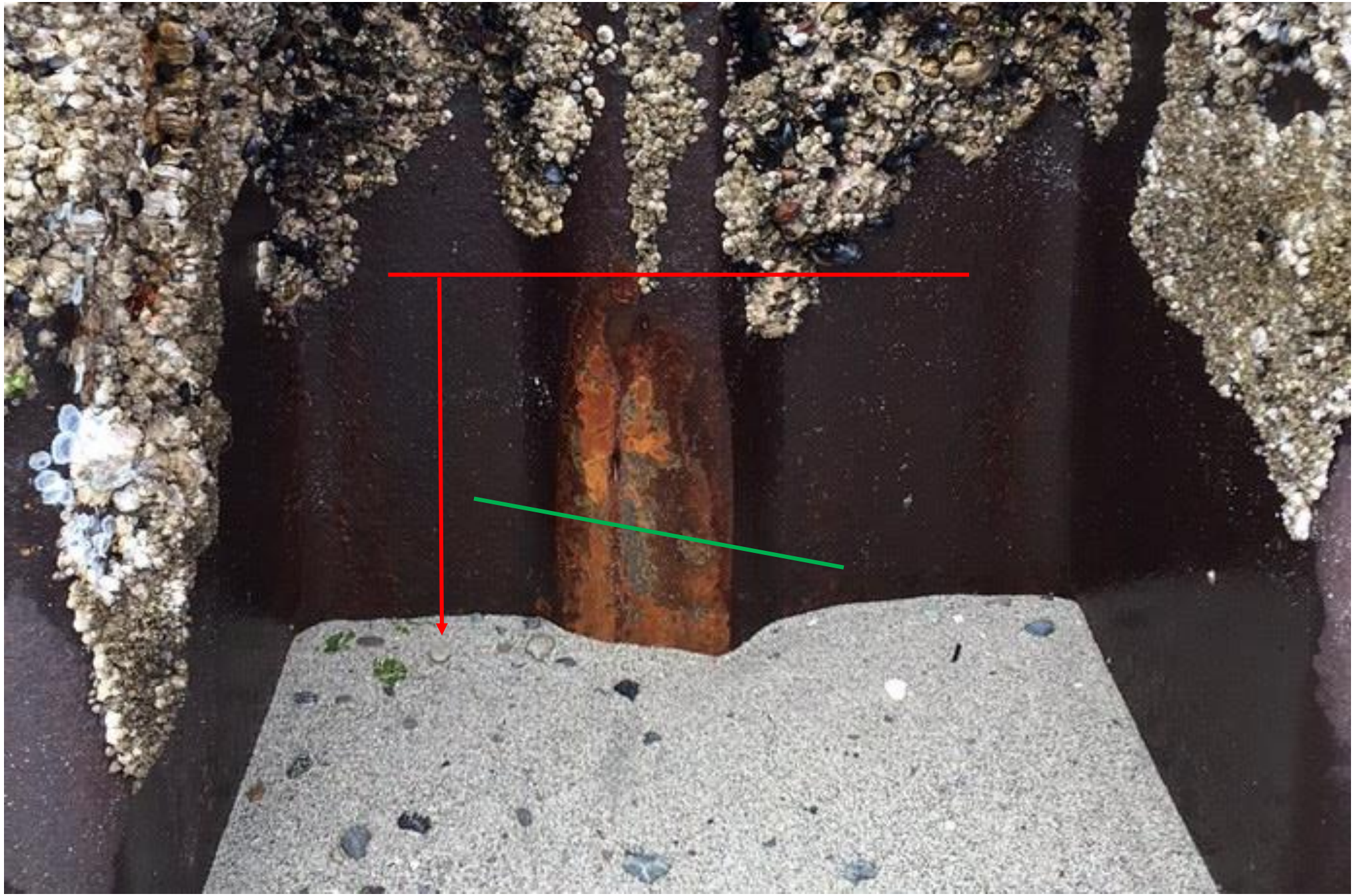
Pile was never interlocked

Severe corrosion
Lamination
Thinning of web
to approx. 5 mm
Vertical lamination
along exposed lock

Severe erosion of lock knuckle on exterior face and loss of finger thickness

Severe interior face corrosion products

Severe loss of exterior lock thickness at bed level extending approx. 6” upward



Complete erosion of frontal male lock finger at bed level